

Institution: Newcastle University
Unit of Assessment: UoA 6: Agriculture, Veterinary and Food Science
Title of case study: Biodiversity management of UK upland hay meadows
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>The way in which UK upland hay meadows are managed and restored to conserve botanical diversity has been largely determined by research carried out at Newcastle University. Increased post-war agricultural production has converted most species-rich upland hay meadows to species-poor rye-grass grassland so that today only 1070 ha (hectares) undisturbed hay meadow remains. The Newcastle research has been used by Natural England (an executive non-departmental public body responsible for England's natural environment) to produce targeted management prescriptions for 2500 ha of farmland in northern England and has informed National Park and AONB (Area of Outstanding Natural Beauty) management on best practice for successful restoration of hay meadows. The research has ensured the successful restoration of more than half of the remaining upland hay meadows in England.</p>
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>The rapid loss of biodiversity associated with the agricultural improvement of hay meadows has meant there is an urgent need for research into conservation and restoration management strategies. There have been three significant groups working on UK hay meadows; two of these have concentrated on lowland areas (Institute of Terrestrial Ecology, now the Centre for Ecology and Hydrology; and the Institute for Grassland and Environmental Research, now Rothamstead North Wyke) whereas Newcastle University has been uniquely focused on the uplands. Questions about which biological and management factors contribute to high plant diversity in upland hay meadows have driven the research at Newcastle University between 1993 and 2008 led by Roger Smith (senior lecturer 1979 to 2013) and with Robert Shiel (lecturer/senior lecturer 1989 – present).</p> <p>The work has involved a combination of long-term field experimentation and detailed ecological studies. Field experiments have explored the effect of different management treatments on the yield and character of the vegetation. These treatments included the application of mineral fertiliser and farmyard manure, the sowing of seed to introduce new species, changes to the date at which meadows were closed up for the growth of the hay crop, the date on which that crop was harvested, and the timing and type of livestock grazing in spring and autumn.</p> <p>In parallel, more fundamental studies were employed to investigate and explain the mechanisms involved in the ecological changes observed. These included the links between the vegetation above-ground and microbial populations in the soil, the effects of the hemi-parasite <i>Rhinanthus minor</i> on the growth of other plant species, on soil microbial communities and on soil nitrogen mineralisation, and the supply of seeds for the recruitment of new individuals and species.</p> <p>The results have shown that to maintain or increase botanical diversity in these hay meadows:</p> <ol style="list-style-type: none"> 1. Autumn grazing is essential but grazing in late spring, especially with sheep must be avoided [P2, G1, G4]. 2. The presence of <i>Rhinanthus minor</i> (hay rattle) is essential in order to reduce the abundance of competitive grasses and encourage the herbs [P5, G2]. 3. The optimum date for cutting hay is in mid-July [P1, G1]. 4. Sowing of seed is essential to introduce new species [P2, P3, G1]. 5. Small amounts of mineral fertiliser might be tolerable for restoration unless they are used in combination with large annual applications of manure, but are best avoided on existing species-rich swards [P2, P4, G2].

6. The restoration of high fungal: bacterial ratios in soil, typical of low fertility environments can only be re-established after several years of appropriate management [P6, G2, G3].
7. Meadow grasslands on low fertility soils can have greater plant species diversity than calcareous, wet or acidic grasslands [G3].

3. References to the research (indicative maximum of six references)

- [P1] Smith, R.S., Pullan, S. & Shiel, R.S. (1996). Seed shed in the making of hay from mesotrophic grassland in a field in northern England: effects of hay cut date, grazing and fertiliser in a split-split-plot experiment. *Journal of Applied Ecology*, 33, 833-841 (Scopus citations: 19)
- [P2] Smith, R.S., Shiel, R.S., Millward, D. & Corkhill, P. (2000). The interactive effects of management on the productivity and plant community structure of an upland meadow: an 8-year field trial. *Journal of Applied Ecology*, 37, 1029-1043 (Scopus citations: 70; ISI Journal Impact Factor from 2000: 2.091)
- [P3] Smith, R.S., Shiel, R.S., Millward, D., Corkhill, P. & Sanderson, R.A. (2002). Soil seed banks and the effects of meadow management on vegetation change in a 10-year meadow field trial. *Journal of Applied Ecology* 39, 279-293 (Scopus citations: 53; ISI Journal Impact Factor from 2002: 2.902)
- [P4] Smith, R.S., Shiel, R.S., Bardgett, R.D., Millward, D., Corkhill, P., Rolph, G., Hobbs, P.J. & Peacock, S. (2003) Soil microbial community, fertility, vegetation and diversity as targets in the restoration management of a meadow grassland. *Journal of Applied Ecology* 40, 51-64 (Scopus citations: 65; ISI Journal Impact Factor from 2003: 3.205)
- [P5] Bardgett, R. D., Smith, R.S., Shiel, R.S., Peacock, S., Simkin, J.M., Quirk, H., Hobbs, P.J. (2006) Parasitic plants indirectly regulate below-ground properties in grassland ecosystems. *Nature*, 439, 969-972 (Scopus citations: 46; ISI Journal Impact Factor from 2006: 26.681)
- [P6] Smith R.S, Shiel, R.S., Bardgett, R.D., Millward, D., Corkhill, P., Evans, P., Quirk, H., Hobbs, P.J. & S.T.Kometa (2008) Long-term change in vegetation and soil microbial communities during the phased restoration of traditional meadow grassland. *Journal of Applied Ecology* 45, 670-679 (Scopus citations: 18; ISI Journal Impact Factor from 2008: 4.560)

Key research grants:

- [G1] The Ministry of Agriculture, Fisheries and Food. £95K 1996-99. *The restoration of diversity to agriculturally improved meadowland*. Principal investigator R.S.Smith; co-investigators: R.S. Shiel, School of Agriculture, Food and Rural Development, University of Newcastle upon Tyne; R.D. Bardgett, School of Biological Science, University of Lancaster; J.C. Frankland, Institute of Terrestrial Ecology.
- [G2] The Ministry of Agriculture, Fisheries and Food. £377K 2000-2004. *Ecological mechanisms affecting the restoration of diversity in agriculturally improved meadow grassland*. Principal investigator R.S. Smith; co-investigators: Dr R.S. Shiel, School of Agriculture, Food and Rural Development. University of Newcastle upon Tyne; R.D. Bardgett, Department of Biological Sciences, University of Lancaster; J.C. Frankland & H.E. Jones, Centre for Ecology and Hydrology.
- [G3] Department of Environment, Food and Rural Affairs £670K (£132K to Newcastle) 2004-12. Diversification of grassland through the manipulation of plant-soil interactions and the identification of indicators of restorability. A consortium project between R.D. Bardgett (Principal Investigator, Lancaster University), J. Tallwin (North Wyke, IGER), V.K.Brown & S. Mortimer (CAER, Reading University), R.S.Smith and R.S.Shiel (University of Newcastle).
- [G4] Department of Environment, Food and Rural Affairs £527K 2008-12. Spring grazing in northern hay meadows: influence of the timing and intensity of sheep grazing on the floristic diversity and restorative potential. R.S.Smith and R.S.Shiel, University of Newcastle

4. Details of the impact (indicative maximum 750 words)

The importance of upland hay meadows

Species-rich upland hay meadows are an important part of the UK's cultural and rural heritage. These floristically diverse grasslands are unique to the UK and limited to sites between 200 and 400 m above sea level. Traditionally, low fertility soils combined with grazing and cutting regimes resulted in high plant species diversity with typically over 30 species per square metre. They also support a variety of insect pollinators and provide breeding habitat for endangered upland bird species such as black grouse and curlew. Although there is no quantitative data it is likely that upland hay meadows have declined considerably in the second half of the 20th century mirroring the 97 % decline in lowland hay meadows (Jefferson (2005) *Grass and Forage Science*, 60, 322–331). Conversion to species poor grassland as a result of modern farmland management practices and priorities has meant that there is as little as 1070 ha of pristine upland hay meadow remaining in Britain. Consequently they are listed as UK Biodiversity Action Plan (BAP) priority habitats (see <http://jncc.defra.gov.uk/page-5706> for more information) and are listed on the European Habitats directive which means that they have the highest conservation priority.

The impact of Newcastle research on upland hay meadows

Newcastle research “...has made a huge contribution to our understanding of hay meadow conservation, and underpinned the development of agri-environment measures for their conservation.” Prior to the research “management prescriptions...were simplistic and did not allow flexibility to acknowledge different situations and starting conditions. There was limited understanding of the timescales and trajectories of meadow restoration and the mechanisms underpinning restoration. The [Newcastle] research, along with results from scheme monitoring, led to pro-active enhancement activity to re-introduce and establish species lost through intensive agricultural practice” [E1, Senior Specialist, Natural England].

Impact on policy and practice – the Higher Level Stewardship Scheme

This increased understanding of upland hay meadow dynamics stemming from the research has been incorporated into the UK government's Higher Level Stewardship Scheme. The scheme, administrated by Natural England, offers payments to farmers, land managers and tenants in England in return for complex environmental management in certain priority areas including the uplands. This scheme requires support and advice from Natural England advisers to develop a comprehensive agreement that achieves a wide range of environmental benefits.

Farmers, land owners and tenants can identify hay meadows on their land using the Farm Environment Plan manual (2010; [E7]). This manual has used the Newcastle University research to develop an identification key (key 2b, page 77) which allows farmers to identify which meadows can be included in the Scheme. Natural England advisers then use Technical Information Notes (TINs) to develop strategies for upland grassland management and to set indicators of success used to judge the restoration of species-rich grassland under the Higher Level Stewardship scheme (options HK6, “maintenance of...” and HK7 “restoration of species-rich semi-natural grassland”). These TINs have been heavily influenced by Newcastle's research. For example, the targets of restoration success identified through the research [P4] have been incorporated in to TIN 050 (2009) [E1, E2]. The finding [P5] that yellow rattle directly influences increased plant diversity and indirectly increases nitrogen cycling in upland hay meadows has been incorporated in to TIN 060 (2009) [E1, E2].

Recently, Newcastle research has contributed to the evidence-base that underpins Natural England's approach to delivery of agri-environment schemes and partnerships with hill-farming communities in relation to nutrient additions and spring grazing and hay cutting regimes [E3]. The Natural England evidence-review (2013) [E3] cites the Newcastle team in justifying its approach to management questions such as; “Which spring grazing levels and shut-up dates maintain floristic diversity and breeding bird populations of upland hay meadows?” The outcome of this evidence

review has fed into the broader process of developing Natural England's advice to land owners and managers.

The impact of this policy and practice on upland hay meadows

As a result of these policies and management prescriptions arising from Newcastle research, 2500 ha has been placed under grassland management options (as upland hay meadows or restoration toward this) in the Higher Level Stewardship scheme in the Yorkshire Dales and North Pennines National Character Areas, with further areas (exact area unknown) in Cumbria [E1]. Decline in hay meadows still occurs due to a variety of causes, but there is recent evidence that previously degraded sites have improved [E4].

“Newcastle University’s research has...directly led to the setting up of successful meadow restoration projects in the Yorkshire Dales National Park and the North Pennines Area of Outstanding Natural Beauty (AONB) (and elsewhere), and hence has supported efforts to safeguard the remaining species-rich meadows and to enhance and extend the meadow resource”[E5, Hay Time Project Officer, Yorkshire Dales National Park]

Active restoration has taken place through local partnership projects involving seed and hay collection and transfer, covering 290 ha in the Yorkshire Dales, 240 ha in the North Pennines and 100 ha in Cumbria [E1]. These hay meadow restoration projects have benefited from the research through, for example, understanding the need to include hay rattle seeds to facilitate the colonisation of other species at later stages in development. In the Yorkshire Dales, this insight fundamentally underpinned the hay time project and without it the scale of restoration would have been greatly reduced [E5]. Seventy meadow restoration schemes have been launched in the Dales resulting in locally-harvested seed (mostly from the same dale) being added to 143 fields (281 ha). All restoration meadows were re-surveyed in 2011 and key species have been successfully restored to meadows in their 69 schemes covering 279ha [E5 & E6]. Projects across the Yorkshire Dales National Park, North Pennines ANOB and the Forest of Bowland ANOB cover 60% of the remaining upland hay meadow in England.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[E1] Testimonial from Natural England

[E2] Technical Information Notes from Natural England

[E3] Pinches, C.E., Gowing, D.J.G., Stevens, C.J., Fagan, K. & Brotherton, P.N.M. (2013) Natural England review of upland evidence – Review for Hay Meadow Management; What management regimes maintain the diversity of meadow flora and populations of breeding birds? Natural England.

[E4] Hamilton, H., Jackson, S. & Blackshaw, A. (in prep) Long-term effectiveness of Environmental Stewardship in conserving upland hay meadows in the Pennine Dales. Monitoring contract report for Natural England. Penny Anderson Associates

[E5] Testimonial from Hay Time Project Manager, Yorkshire Dales National Park

[E6] Hay Time Final report, Yorkshire Dales National Park

[E7] Natural England (2010) Higher Level Stewardship Farm Environment Plan (FEP) Manual. Technical guidance on the completion of the FEP and identification, condition assessment and recording of HLS FEP features